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SC SYNCHROTRON AND GANTRY BASED ON CANTED COSINE THETA MAGNETS

E. Benedetto,
N. Al Harbi, U. Amaldi, D. Bergesio, A. Garonna, V. Ljubicic, P. Riboni,
TERA Foundation

Collaborators:

G. Arduini, D. Tommasini, ***CERN***
B. Auchmann, ***CERN/PSI***
L. Brouwer, S. Prestemon, ***LBNL***

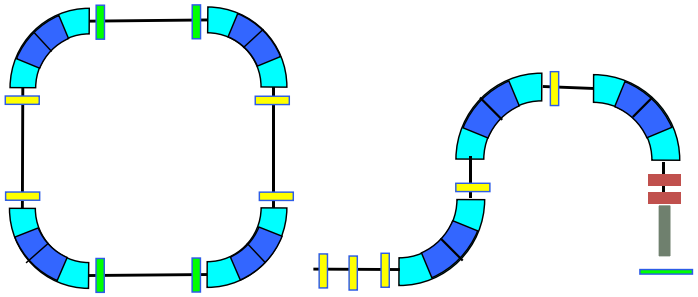
Experts:

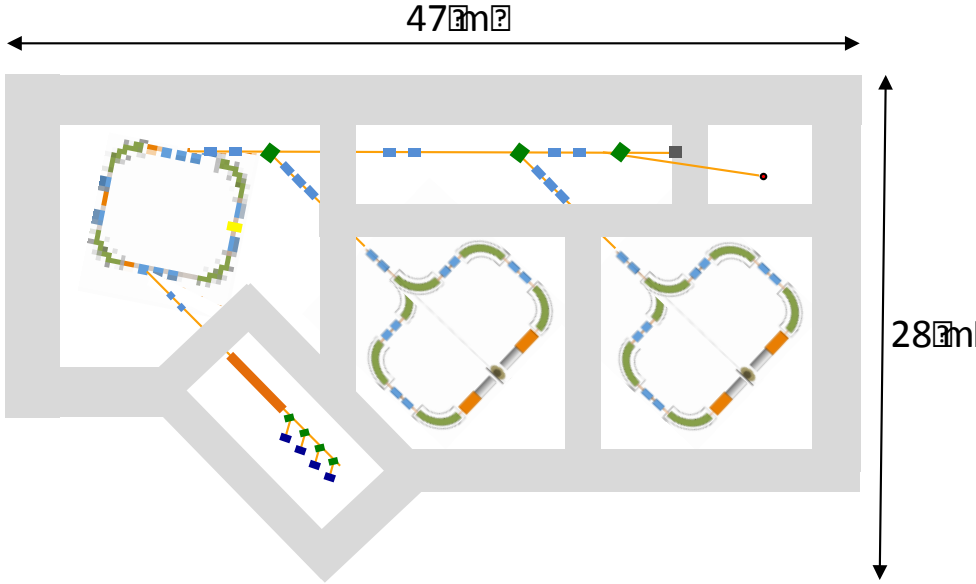
F. Wenander, J. Pitters, C. Carli, S. Benedetti, M. Martino, ***CERN***
A. Pikin, ***BNL***

TERA

Proposal: Compact synchrotron and gantry

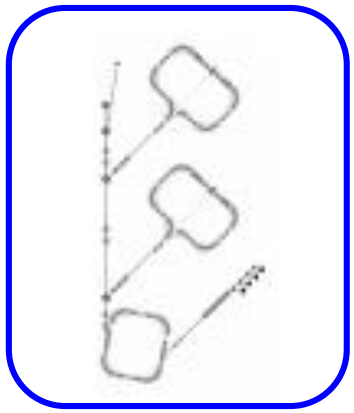
- C^{6+} up to 430 MeV/u
  - …and other light ions (He)
- Full treatment in one cycle
  - 10^{10} C^{6+} (10x10x10 cm^3 target)
- SC technology (CCT) makes it compact
  - Ring: ~27 m length
  - Gantry: 5.3 m height

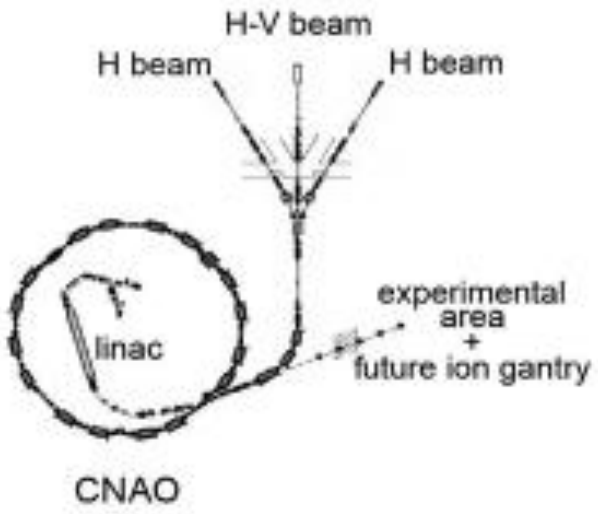


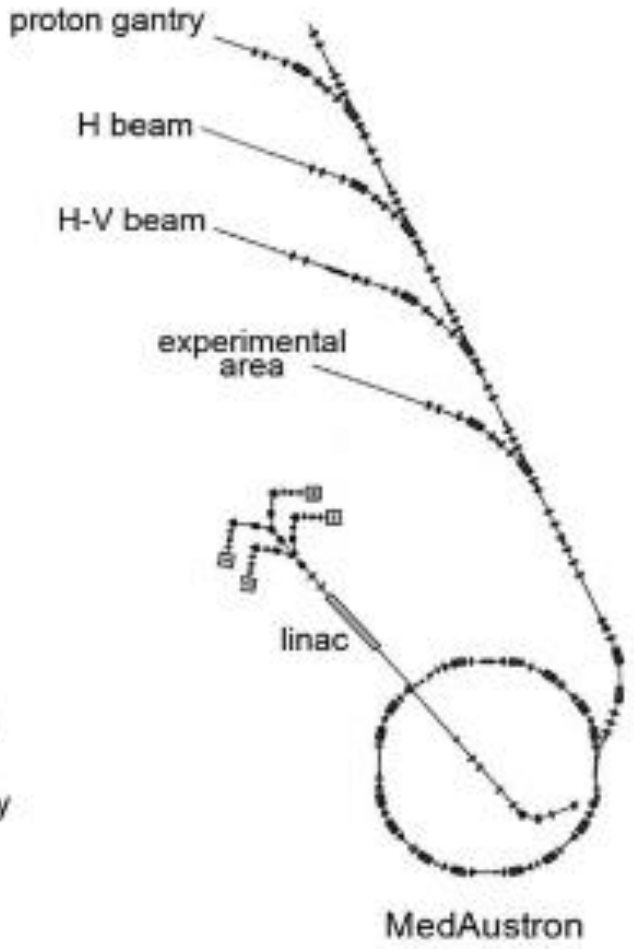


Proposal: Compact synchrotron and gantry

- Compact! compared to PIMMS-derived facilities







Outline

Magnets technology

Synchrotron

Lattice

Injection/extraction considerations

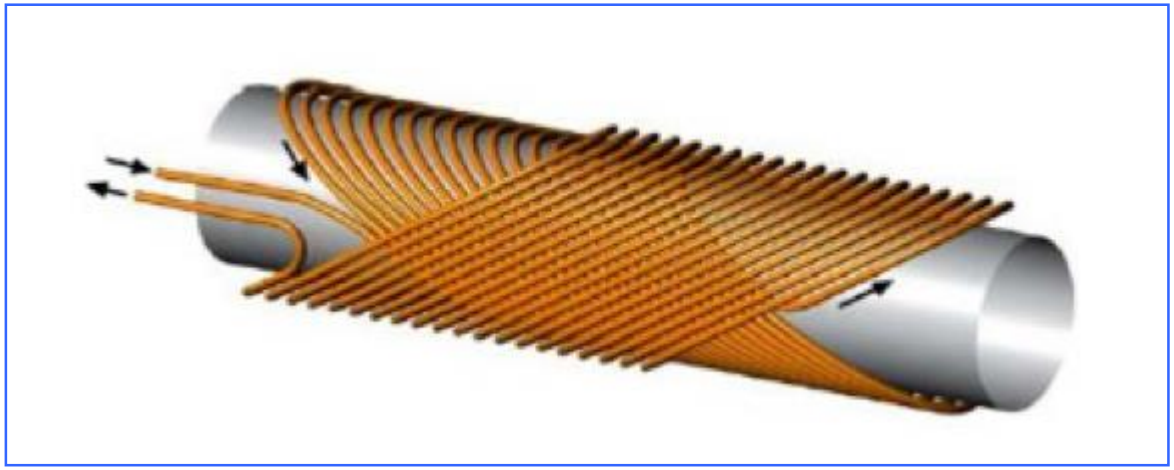
Gantry

Optics and mechanical

Dose delivery

Magnets: Canted Cosine Theta

- ✓ Pure dipole field
  - 2 tilted solenoids



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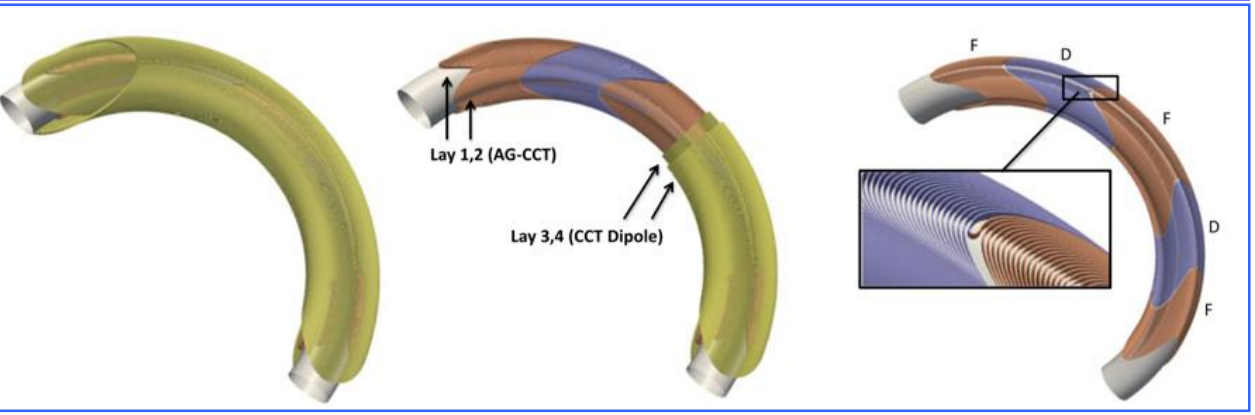
Design of an Achromatic Superconducting Magnet for a Proton Therapy Gantry

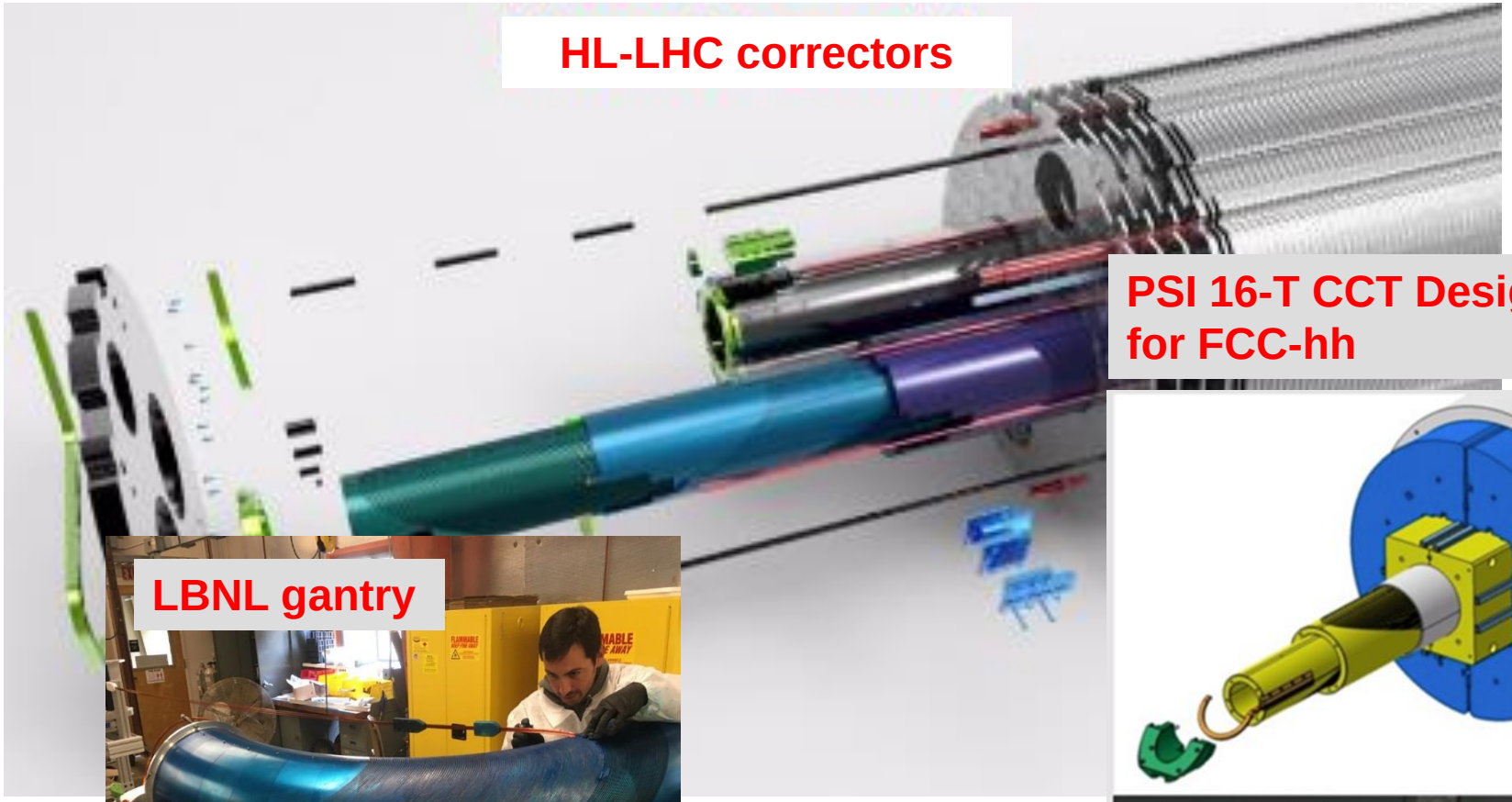
L. Brouwer, S. Caspi, R. Hafalia, A. Hodgkinson, S. Prestemon, D. Robin, and W. Wan



- ✓ Nested quadrupoles
  - add extra layers

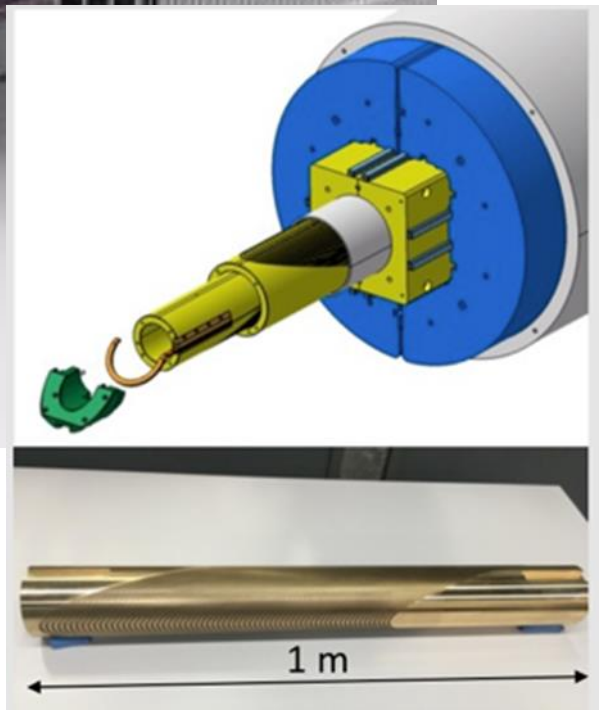
Magnets: Canted Cosine Theta

HL-LHC correctors

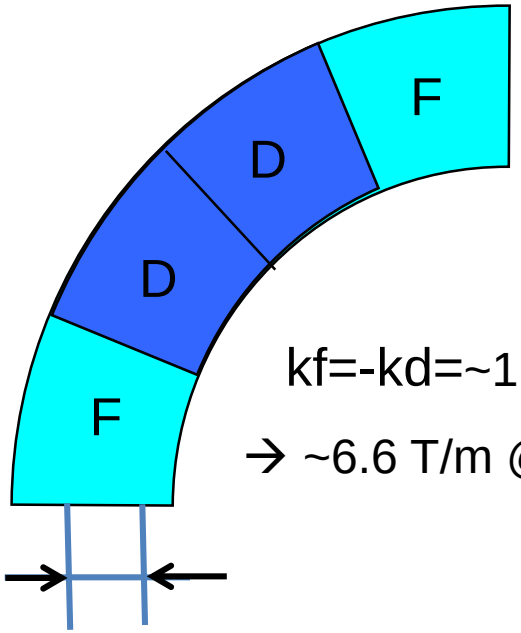


LBNL gantry

PSI 16-T CCT Design for FCC-hh



Magnets for the optics



kf=-kd=~1 m^{-2}

→ ~6.6 T/m @ 3.5T

Design choices:

- 90^0 bends with nested quads
- Powered in series
- Bmax=3.5 T
- ρ=1.90 m

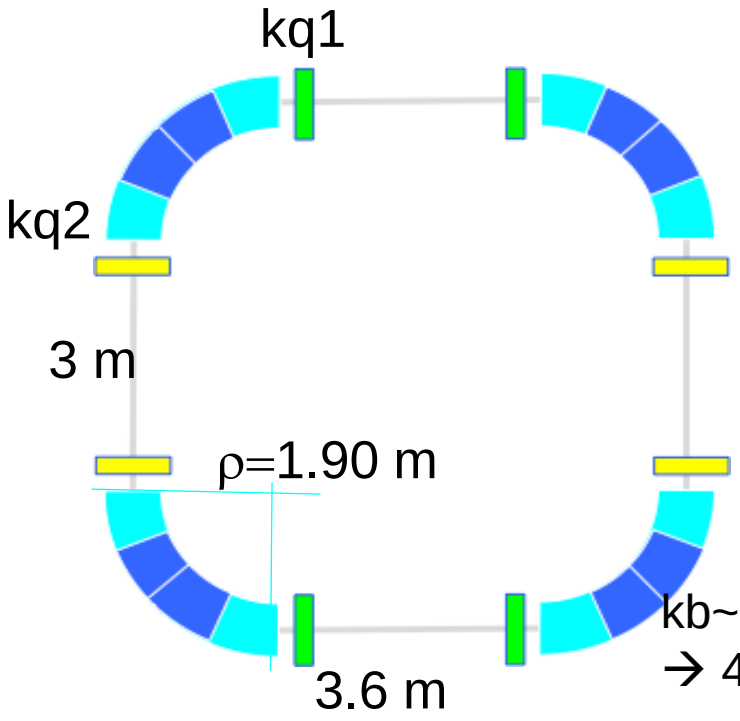
PRELIMINARY

Apertures magnets (g.f.r.) diameter:

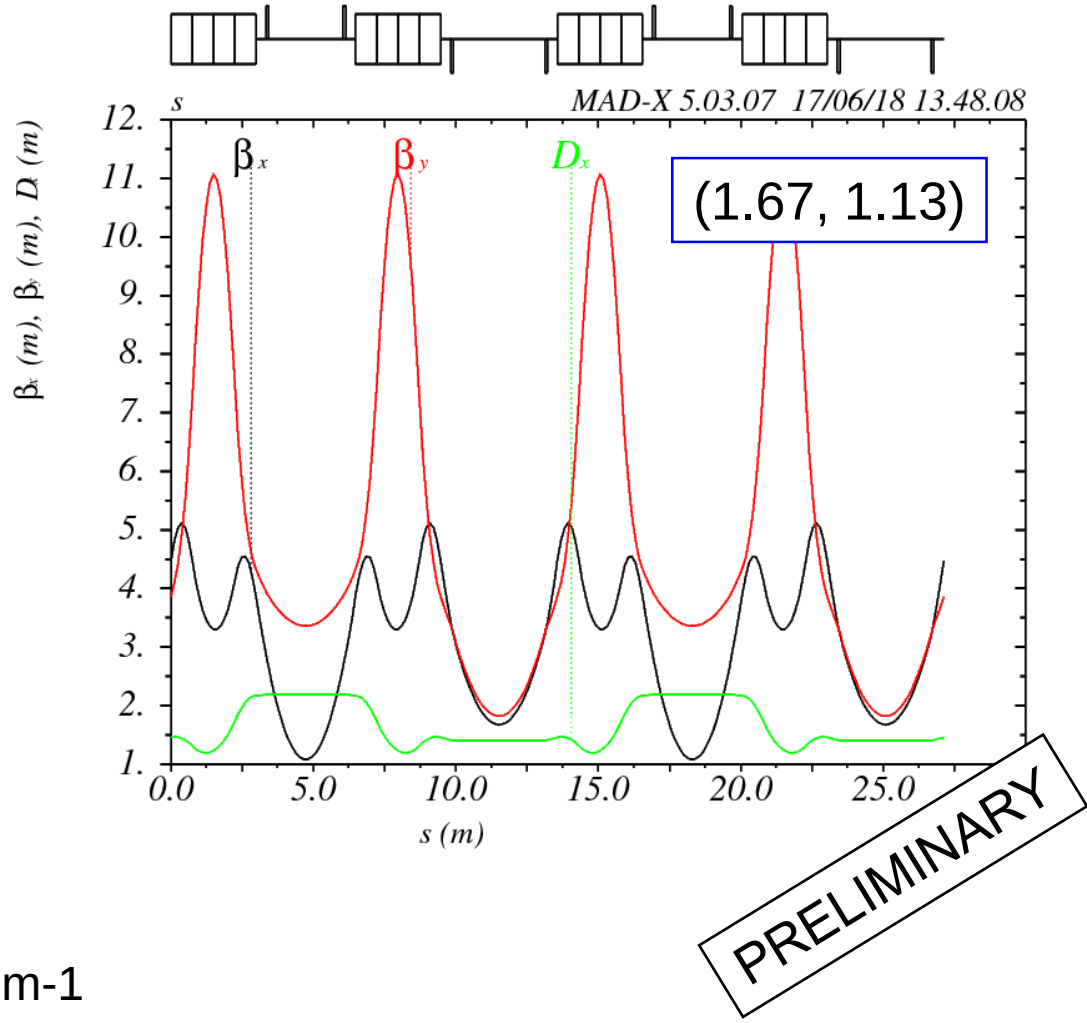
- Gantry: 30 mm
- Ring: 60 mm

Lattice

- γ_{tr} >1.43(@430 MeV/n)
- Qx~1.67 for slow extraction



kb~0.6 m-1
→ 4 T/m @ 3.5T



Injection, Linac & Source

MultiTurn injection @ 10 MeV/u:

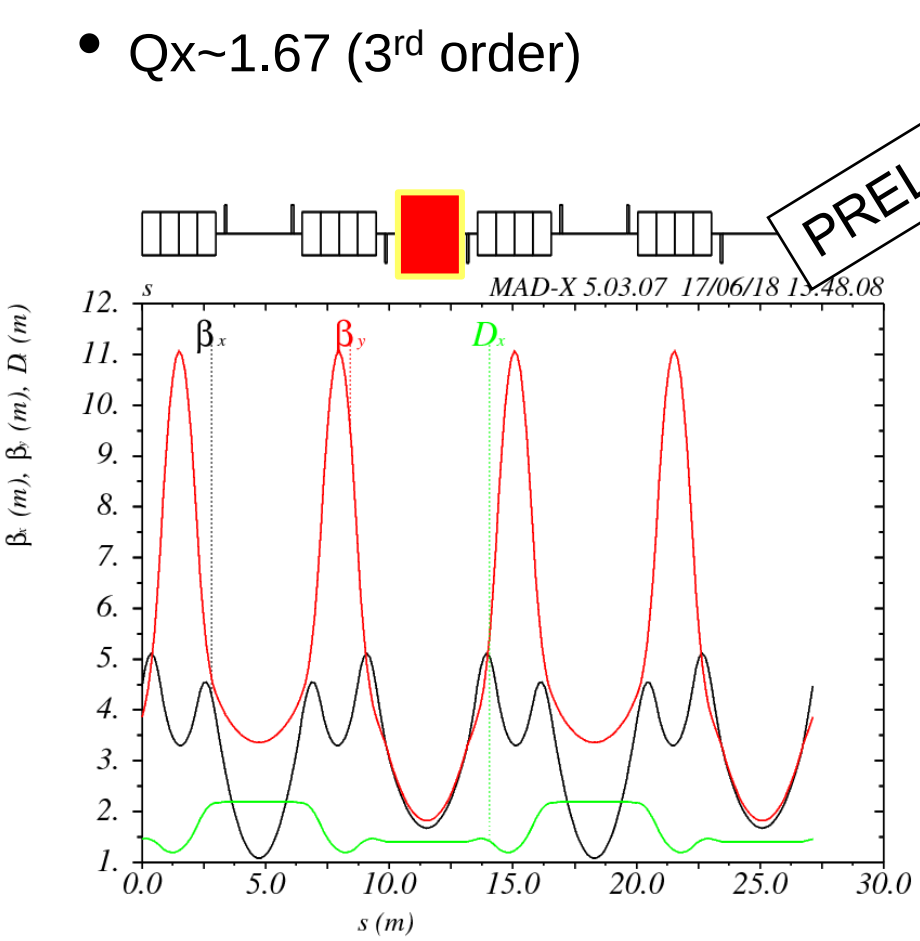
Need ~10^{10} C^{+6} in ~100 turns x 0.6 μs (rev. period)

Synergies with CERN:

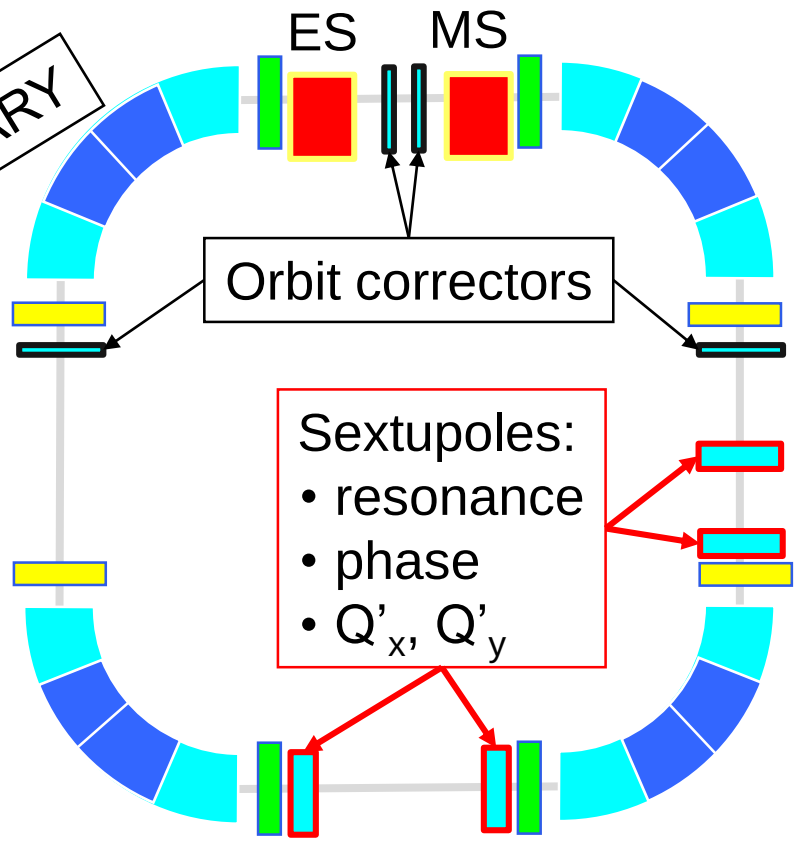
- EBIS MEDeGUN (F. Wenander et al.)
  - compact source (1A e- current) w. small emittance: ~0.03π mm mrad, norm.
  - C^{+6} ions, short pulses @180 Hz (developed for CABOTO linac)
  - we need longer trap length, i.e. 1m (vs. 25 cm) & no rep. rate requirements
  - 10^{10} is on the limit **!!!**
  - OR: source as ~RHIC EBIS (5A e- current, larger intensity but also emittance)
- High frequency RFQ for ions (V. Bencini, A. Lombardi et al.)
- IH structure (S. Benedetti et al.)

Extraction

- Slow extraction with RF knock-out
- Qx~1.67 (3rd order)



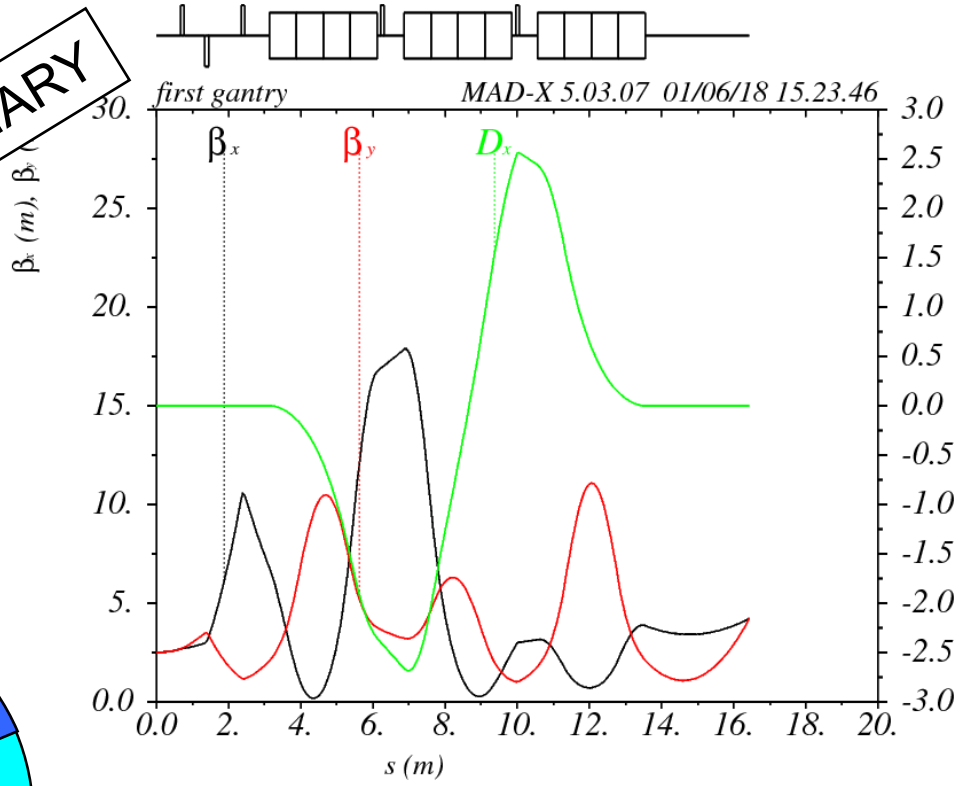
$\Delta\mu \sim 90^0$ between septa



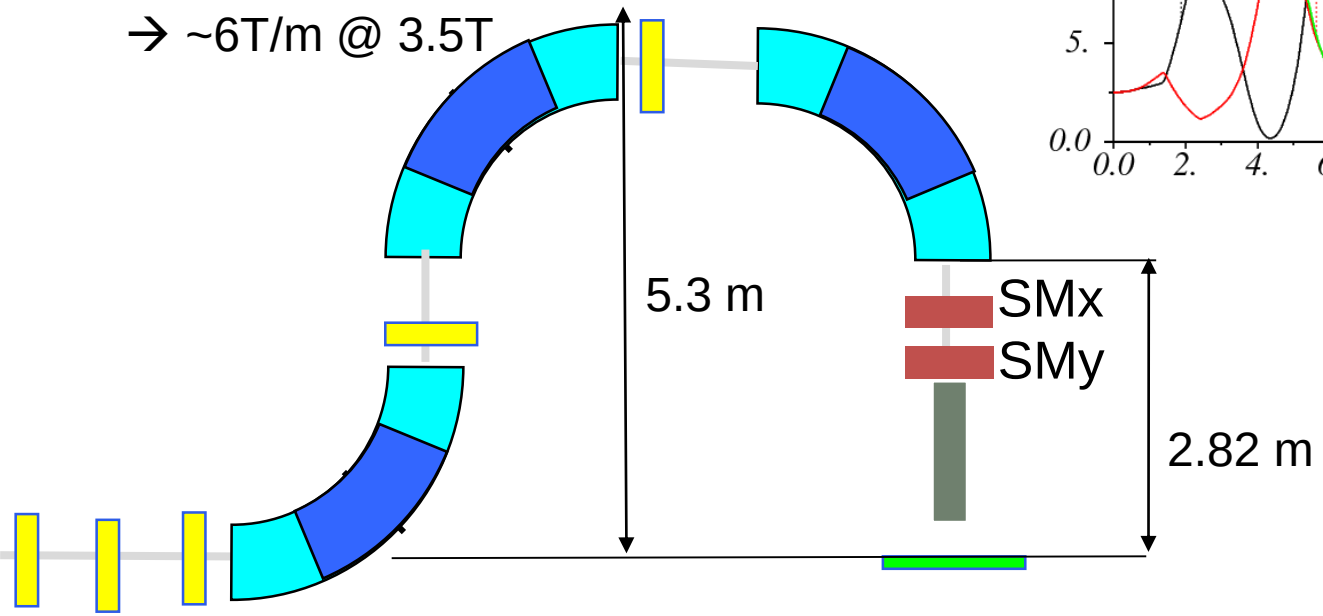
Gantry

PRELIMINARY

- Rotation independent
- Achromat
- RE11=RE33=1.3
- FWHM=4mm @ isocenter

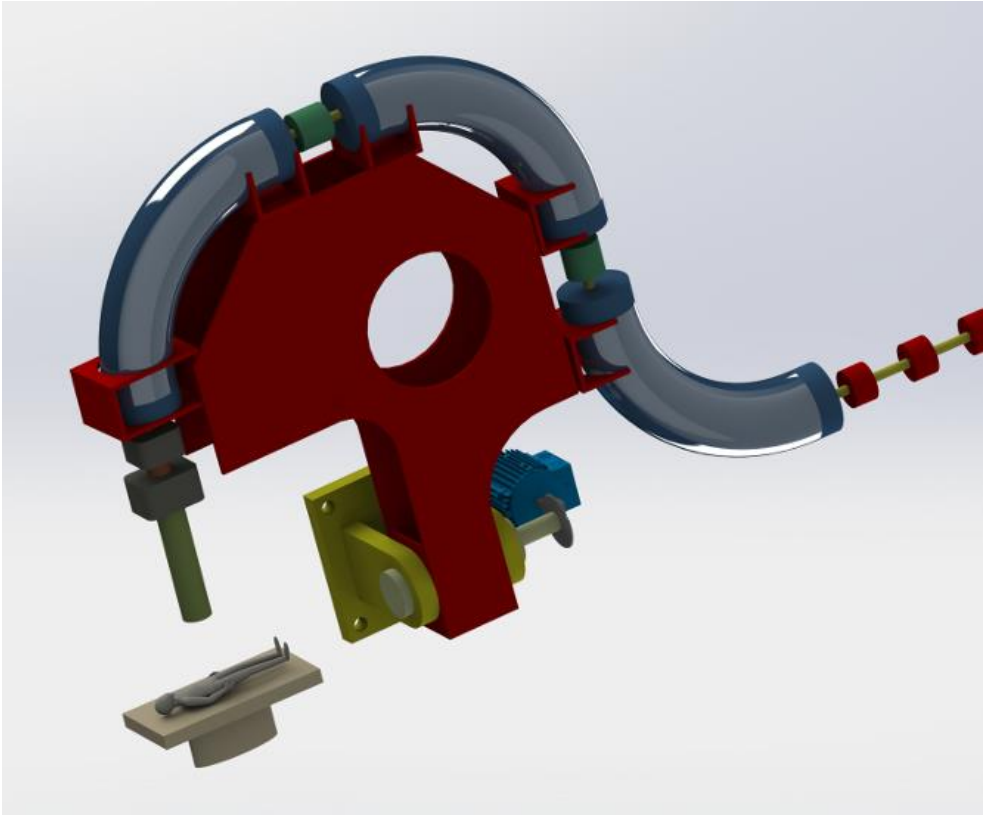


kb=0.8m^{-2}
→ ~6T/m @ 3.5T

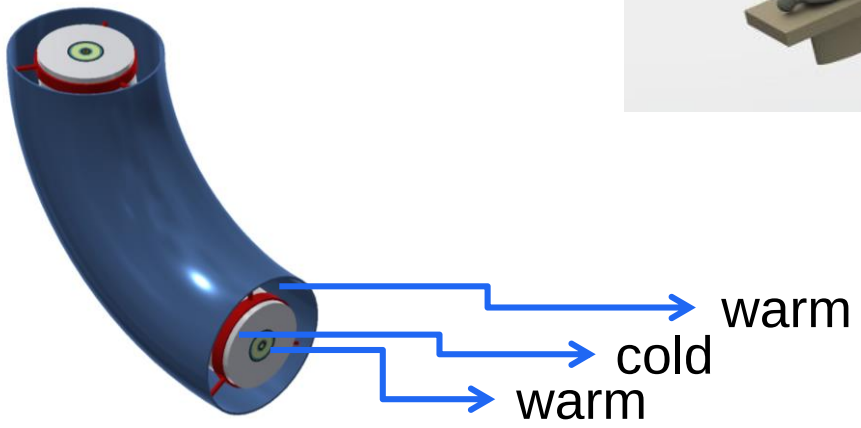


Gantry mechanical concept

- Radius ~5.3 m
- < 20 T (without supports)



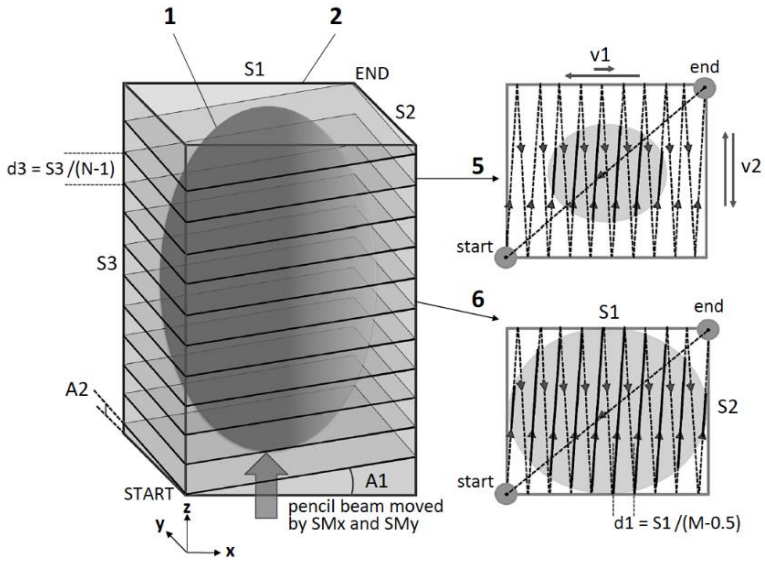
- Magnet:
  - gfr (chamber)=15 mm radius
  - Outer radius (iron)= 370 mm



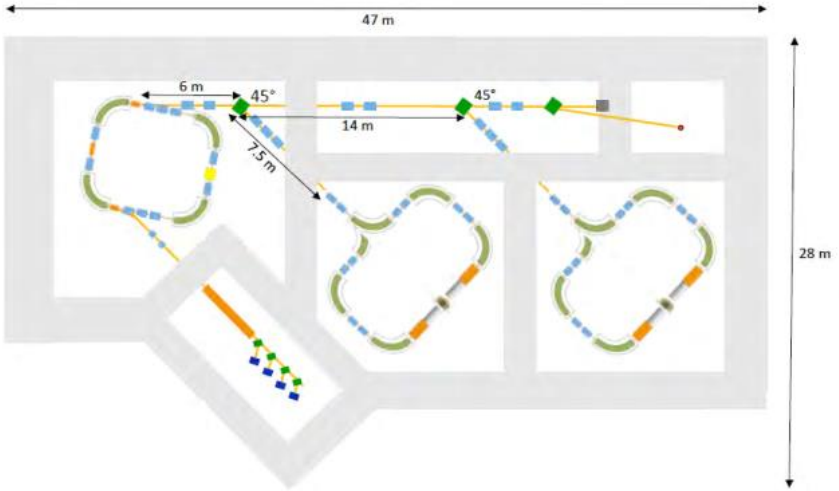
Extraction and dose delivery

- Field stability at extraction → reduce intensity spikes
  - CCT dipoles windings have large inductance (not the quads)
  - All dipoles and nested quads powered in series + current trims
  - Switch mode power supplies (>50kHz)

- Oblique Raster Scanning method → see A.Garonna's talk
  - Assuming 10x10x10 cm^3 volume:
    - ✧ Dose delivery in 20s **FAST!!!**
    - ✧ 10^{10} C^{6+}
  - dB/dt ~0.05 T/s **SLOW !!!**
    - ✧ Ramp ~60s (10→ 430 MeV/u)
    - ✧ Less cryogenics for SC magnets
    - ✧ Eddy currents ~negligible



Summary



- Proposal of compact design:
  - with Canted Cosine Theta magnets
  - Bmax=3.5T
  - 90^0 bends with nested quads
  - Ring 27 m, gantry R=5.3 m

- Preliminary study of Synchrotron & Gantry

- Synergies with CERN developments:
  - Canted Cosine Theta magnets, for HL-LHC
  - High frequency RFQ, IH and MEDeGUN EBIS, for medical C^{6+} linac